A SPAWNING ESCAPEMENT OBJECTIVE METHODOLOGY FOR CHINOOK SALMON, COHO SALMON AND STEELHEAD TROUT: MAXIMUM SUSTAINABLE SMOLT PRODUCTION (MSSP)

Prepared by Sam Wright for Washington Trout, Duvall, WA.

In the mid-1980s, a steelhead (*Oncorhynchus mykiss*) spawning escapement methodology was developed to determine smolt production potential in each river system. From this statistic, the necessary adult escapement could then be determined (Gibbons et al. 1985). Extensive counts of steelhead parr were made in all types of stream rearing habitats. These counts were limited to areas which were believed to be fully seeded by adequate adult spawning escapements. Values were then developed for average rearing densities per unit of area in each type of stream habitat. The production potential for each watershed could then be determined. Each stream is unique but, in terms of juvenile steelhead production potential, it is only a unique collection of similar segments. This is management for Maximum Sustainable Smolt Production (MSSP). It requires spawning escapements that are about 20% higher than would be calculated from adult to adult spawner-recruit relationships for Maximum Sustainable Yield (MSY). This difference is due to conservative life history stage conversion numbers used by Gibbons et al. (1985) and/or failure to achieve maximum smolt production in some or most years under MSY management.

The primary key to future success in managing wild salmon and steelhead resources lies in selection of correct spawning escapement objectives and then attaining them a high percentage of the time. Four salmonid species, Atlantic salmon (*Salmo* *salar*), chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*) and steelhead form a category that has certain important characteristics in common. All have a history of active quantitative management, all have significant freshwater juvenile rearing, and all are limited by juvenile rearing potential of their freshwater habitat. Some might dispute the limiting factor for chinook with first year seaward migrants (ocean type), but historical and/or current production of different Washington chinook populations is directly related to size of watershed and amount of freshwater rearing habitat accessible to chinook. Some of the larger adult runs have little or no estuary area for juvenile rearing (Phinney and Bucknell 1975; Williams et al. 1975).

There is a logical five step progression toward determining best basis for successful management but this progression can be halted by a lack of essential data. For example, historical data bases are generally limited to numbers of fish even though Beverton and Holt (1957) originally formulated their stock recruitment model by measuring adult stock as number of eggs deposited, not number of fish. All four species began their active fisheries management history with adult to adult spawner-recruit relationships. This provided for successful management of Atlantic salmon prior to advent of major high seas fisheries (Elson 1957).

Chinook relationships were used to manage spring, summer and fall runs in the Columbia River and runs in the Skagit River. All of these were flawed by not fulfilling a mandatory requirement of total catch and escapement numbers for recruits. Ocean catches were missing in all cases and Puget Sound recreational fishery catches were missing from the Skagit relationship. An adult to adult relationship was used for coho salmon from the Oregon coast but it had the flaw of assuming a constant year-to-year exploitation rate. Results from marking and tagging studies clearly show that this was not true (WDF 1992; WDFW 1997). The only early use for steelhead was in the upper Columbia River and this was valuable in pinpointing decline in productivity due to construction of multiple dams (WDFW 1997). More recent relationships for steelhead in western Washington have shown so much variability that they have raised more questions than answers (WDFW 1997). This is also a species with repeat spawners and a large run will, on average, produce the greatest number of repeat spawners. Fisheries are selecting against this group since they are being fished twice.

The second stage in a logical progression was limited mainly to Atlantic salmon. As high seas fisheries started to heavily exploit populations, managers found that their adult to adult relationships were breaking down. Spawning runs had declined but recruits from these runs were declining at a much steeper rate. When managers looked closely at spawners, it was found that the average female was much smaller and percentage of males was significantly higher. Pounds of females was used instead of numbers of fish to better reflect a greatly diminished egg potential (Elson 1957, 1975).

This should have sounded a warning to chinook salmon managers since both species had high and increasing ocean exploitation rates and both were experiencing declines in both percentages and sizes of females. The relationship for Skagit River chinook predicted too high a return for four consecutive years in the late 1960s and was discarded. It began tracking the up and down variations in odd year pink salmon (*O. gorbuscha*) runs, which are known to be highly sensitive to flooding during egg incubation (Wickett 1958). However, the chinook problem (peak flood flows during egg incubation) could not be confirmed until the 1990s when regular smolt trapping and enumeration was initiated (WDFW 1997). In the interim, all Puget Sound chinook in wild fish management zones had a 12 year average value as their escapement goal, a surrogate for MSY management (Ames and Phinney 1977). Use of a better measure of egg potential should have drawn some interest from steelhead managers since this species has multiple age classes and repeat spawners. However, unlike Atlantic salmon, there was no obvious change in structure of spawning populations.

Chinook salmon management recently regressed all the way back to exploitation rate management. This was last used by the federal government in their failed management of Alaskan salmon resources prior to statehood (Cooley 1963; Holmes and Burkett 1996). Many harvest managers and fishermen favor this approach since all traditional fisheries can be allowed every year regardless of resource status. It is often mistaken portrayed as fishing at an MSY exploitation rate. However, the MSY rate is an average value over time and has no direct application to annual management planning for any resource that has significant year to year fluctuations (Beverton and Holt 1957; Ricker 1975). It would only be used in the sheer coincidence of a completely "average" run. Exploitation rate management is also touted as a "probing" element of adaptive management that will produce a range of spawning escapements and thus create usable knowledge. Management imprecision associated with any strategy will do the same thing. The promise of higher escapements from larger runs (as opposed to MSY management) will never be realized. Anyone who has ever managed fisheries knows that decisions always gravitate to least restrictive options available (Wright 1993). This is why there are "strategies" such as 48 year rebuilding plans for marine fish species (Weeks and Parker 2002).

Stage three in a progression to better management occurred when managers realized they needed to quantify juvenile production resulting from each specific adult escapement. This is the conscious transition from MSY to MSSP management and the steelhead escapement methodology fits in this third stage (Gibbons et al. 1985). While it was originally believed that this was only an interim step toward future use of adult to adult relationships, it is now apparent that this would be a step backwards. By use of a comparable approach, coho salmon management in wild fish management zones from the mid-1970s through the late 1980s also falls in this stage (Zillges 1977).

The fourth stage in progression is reflected in current Atlantic salmon MSSP management in eastern Canada. The relationship used is between eggs per unit of juvenile rearing area and resultant smolt production (Chaput et al. 1998). The transition from juvenile populations in streams to smolts is critical because it fully isolates independent variables of freshwater and marine survival. Coho salmon management was at this stage in the 1990s due to availability of data from long term studies of adult escapement and smolt production. However, coho, like chinook, have recently regressed to exploitation rate management. Steelhead management cannot advance to this fourth stage since managers did not have foresight in the mid-1970s to begin long term smolt enumeration in a number of representative streams. In Washington, the only long term data base of adults and smolts comes from a single small stream (Snow Creek). Steelhead managers are now stuck in the same place where salmon managers were temporarily stuck in the mid-1970s when they tried unsuccessfully to use data from a single small stream (Minter Creek). However, it is never too late to start gathering essential data for improved resource management.

The fifth and final stage in a progression to better resource management is when weighted numbers of females are compared to smolt production. Coho salmon management actually reached this stage in the 1990s because nearly all females are 3-year-old fish (Wright 1970) and there was no need for weighting. Large females have spawning values that are significantly greater than their increase in fecundity. Future chinook and steelhead management needs to be based on weighted numbers of females and resultant smolt production. Data elements needed are numbers and sizes of females and smolts produced. Proper weighting factors will be ones which give best relationships between females and smolts.

Survivors during natural salmonid egg incubation come from the deepest egg pockets (van den Berghe and Gross 1984; DeVries 1997) in larger, more stable spawning gravel (Burner 1951; Hawke 1978). The eggs were placed there by large females (Hankin and McKelvey 1985; Forbes and Peterman 1994) who deliberately select large males as their mating partners (Schroder 1981; Hankin et al. 1993) and are better at defending their nests against dig-up by other fish (van den Berghe and Gross 1989). These same females also have larger eggs (Hankin and McKelvey 1985; Beacham and Murray 1990) which produce fry with higher pre- and post-emergence survival rates (Shelton 1955; Forbes and Peterman 1994).

Net result of these processes is that large female salmonids have demonstrated a productivity that is much greater than can be explained by increase in fecundity alone. For coho, van den Berghe and Gross (1989) estimated the largest females within a spawning population had a 23-fold fitness advantage (measured to time of fry emergence) over the smallest females. Only about one-third of this reproductive differential was attributable to differences in fecundity. Helle (1989) compared the largest and smallest size-classes of chum salmon and found only a 1.2 fold difference in fecundity per parent but a fourfold difference in surviving offspring per parent. The harsher the incubation conditions, the more intense natural selection processes become.

Spawning escapement objectives under MSSP management may be higher than under the only viable alternative, MSY management. The latter has a mixed track record but can be used successfully if escapement objectives are both correct and achieved (Holmes and Burkett 1996; Myers and Barrowman 1996). Critics of MSY management often fail to appreciate the important distinction between system failure and manager failure. The main reason that MSY objectives could be lower is that full smolt production might not be achieved in some or most years. Both systems require use of fixed annual escapement goals until someone is able to accurately predict future environmental conditions. These occur after decisions have to be made which determine balance between catch and escapement. Management basis for MSY can only come from adult to adult relationships and these always show a great deal of variability due to incorporation of both freshwater and marine survival (NRC 1996; WDFW 1997).

For chinook and coho, it is difficult or impossible to get accurate total catch data from mixed stock marine fisheries for recruit statistics. Variability alone makes it much harder to determine correct spawning escapement objectives or to detect long term changes in productivity of populations. When adult to smolt relationships are used as a basis for MSSP management, freshwater survival is isolated. These relationships always have much less variability, making it easier to see correct escapement objectives or detect changes in productivity (WDFW 1997). Thus, MSY management carries a greater degree of uncertainty and risk. The prospect of somewhat greater average yields over time may be an illusion.

The only element of risk with MSSP management is a possibility of density dependent mortality at higher smolt population sizes. However, this can be easily examined because freshwater survival has already been isolated from marine survival. Coho and Atlantic salmon both have extensive data bases of wild smolt enumeration and marine survival rates. Neither species shows any evidence of density dependent mortality (WDFW 1997; Chaput et al. 1998).

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